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GETTING UP TO SPEED

Best Practices for Measuring Broadband Performance

JUNE 2016

About the Authors

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About OTI

The Open Technology Institute (OTI) works at the intersection of technology and policy to ensure that every community has equitable access to digital technology and its benefits. We promote universal access to communications technologies that are both open and secure, using a multidisciplinary approach that brings together advocates, researchers, organizers, and innovators.

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EXECUTIVE SUMMARY

In this paper, we examine ways of empirically measuring broadband internet performance in the United States, and discuss best practices for using that performance data for consumer education on broadband issues. Broadband performance is affected by complicated factors that are not always recognizable to the consumer. Although methodology is often overlooked, different approaches can expose different aspects of performance. The individual merits and drawbacks of a given methodology are contingent on its use case: what do you want to know, and is your measurement designed to uncover it? There may be no "best" single methodology for measuring broadband performance, but there are best practices; the most useful performance data requires a consistent, reproducible methodology that provides full transparency for those using the data into its underlying assumptions, and in turn, the data's strengths and limitations. These principles are considered in a brief case study of the Federal Communications Commission's (FCC) Measuring Broadband America program, and the paper concludes by urging the FCC and internet service providers to better integrate performance measurement considerations into consumer-facing transparency disclosures for broadband service.

> **There may be no "best" single methodology for measuring broadband performance, but there are best practices.**

These recommendations come at a time when conversations about broadband measurement are unfolding in the U.S. and abroad. We hope they are useful to providers as they consider alternatives to the FCC's "safe harbor" for compliance with the 2015 Open Internet Rules, to the FCC itself as it considers adjustments to the Measuring Broadband America program in the future, and to other consumers, researchers, and advocates wishing to better understand broadband measurement. Additionally, issues related to broadband measurement have global implications as well, particularly as the Body of European Regulators of Electronic Communications (BEREC), the regulating agency of the telecommunication market in the European Union, has issued draft guidelines for implementation of the EU's network neutrality rules.[1] The guidelines include an extensive discussion on transparency, and we hope the recommendations here can help instruct best practices abroad.

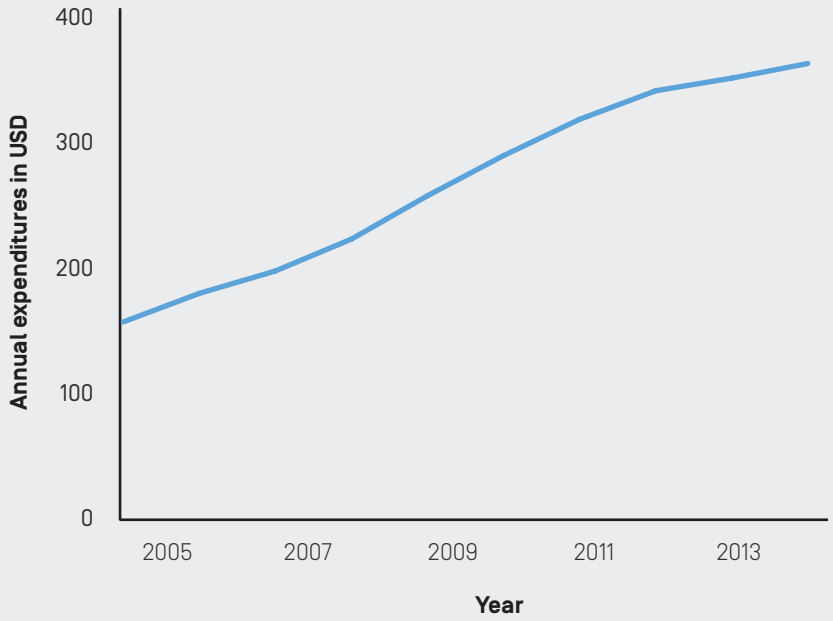
INTRODUCTION

Today, an internet service plan is among the most important purchases that an American household can make. Data from the Pew Research Center indicates that the internet is an essential part of everyday life for many Americans, serving as a gateway to government services, employment resources, educational opportunities, and more.[2] Corresponding to the great leaps in the technology, Americans are also paying more for internet services: the Bureau of Labor Statistics estimated that the average American household spent $357.80 on internet services in 2014, an increase of 232 percent from the $153.94 spent in 2005.[3] Many households are likely spending even more for more robust plans or higher quality services: Federal Communications Commission (FCC) data puts the average annual cost of a standalone broadband in the US at $839.16.[4]

Despite the ascendancy of internet service in American lives and pocketbooks, many consumers struggle to find adequate information about the services that they pay for. A recent Government Accountability Office (GAO) report, prompted by congressional request, highlights how it is often "difficult for consumers to compare broadband services," and documented widespread consumer troubles in accessing broadband performance information such as speed and reliability.[5] In turn, the FCC receives numerous consumer complaints about slow or congested service, services that fall short of advertised speeds, hidden service fees, and billing amounts that exceed advertised rates.[6] Another recent study by the FCC found that 80 percent of broadband users in the United States did not know the speed of their connection, and that a lack of standardized information from ISPs and third parties has exacerbated this consumer confusion.[7] It is not just consumers who face this conundrum: the difficulty of getting accurate information about internet services also confounds small businesses, researchers, and policymakers seeking to better understand the market landscape.

For its part, the FCC has worked to improve the availability of broadband performance information. The FCC has relied on three key policy levers: Open Internet Transparency Rules, mandated consumer-facing disclosures, and transparency requirements in recent merger approvals. In 2011, the FCC launched the Measuring Broadband America program (MBA), a nationwide study of broadband performance. In the same year, the FCC formally implemented its first-ever transparency rules for internet service providers (ISPs). The rules require both fixed and mobile ISPs to publicly disclose accurate information about network management practices, performance,[8] and commercial terms.[9] The 2011 rules stipulated the disclosure of two key performance characteristics: speed and latency. The FCC's transparency rules were further enhanced in the 2015 Open Internet Order, which added packet

Figure 1 | Annual Household Spending on Internet Services



Source: Bureau of Labor Statistics

loss as a third required performance characteristic and stipulated that all disclosures be in terms "of average performance over a reasonable period of time and during times of peak usage" and related to the expected performance experienced by the consumer.[10]

In April 2016, the FCC approved a standardized format for disclosure of ISP performance data (Fig 2). The formats—one for mobile and one for wireline service—are akin to the "Nutrition Labels" used by the Food and Drug Administration and are designed to clearly display commercial and performance information.[11] The labels were developed through a collaborative process with the FCC's Consumer Advisory Committee, on which New America's Open Technology Institute (OTI) played a leadership role. OTI has long advocated for "Truth-in-Labeling" for broadband services and played an active role in developing the consumer disclosure labels.[12] OTI's research embraces the notion that consumers and competition benefits from more, rather than less, information; as such, the FCC's transparency efforts are welcome developments.

While the labels are an important step forward, the method used to collect the data contained in the label required additional guidance.[13] Research shows that integer measurements of the same performance metric on the same network can vary significantly based on the test methodologies, test assumptions, and how the performance data is subsequently aggregated and analyzed.[14] A lack of standardized data collection—or, at the very least, a lack of transparency about the metrics used to collect the data—can still drive consumer confusion, even if that data is reported in an easy-to-read format.

The FCC has historically mandated disclosure of "actual network performance data" that is reasonably related to the end-user's experience, and the FCC's 2011 Advisory Opinion granted ISPs a safe harbor for that requirement as long as they participated in the Measuring Broadband America

Figure 2 | April 2016 FCC Broadband Labels

Broadband Facts

Mobile broadband consumer disclosure

Device Compatibility

If you want to use your existing device, learn more about compatibility.

If you want to obtain a device, learn more about prices and other options.

Choose Your Data Plan - These prices do not include costs for obtaining a device from us.

	High Speed Data allowance per month		
	1GB	3GB	5GB
Monthly charge	**$35.00**	**$45.00**	**$60.00**
When you exceed the data allowance	**$10.00/Additional GB**	**Slowed speeds**	**NA**

Learn more about other included services/features.

Additional pricing options, plans and promotions can be found here.

Coverage Map

Charges and Terms Common to All Plans

Monthly fees	
Administrative fee	**$1.20**
Regulatory fee	**$0.13**
One-time fees	
Activation fee	**$50.00**
Deposit	**$50.00**
Early termination fee	**$240.00**

Government Taxes and Fees, and Other Carrier Surcharges May Also Apply: Varies by location

Performance - Individual experience may vary

3G		4G
Typical speed 1.5 Mbps downstream / 600-900 Kpbs upstream	•	**Typical Speed** 6-12 Mbps downstream / 3-6 Mbps upstream
Typical latency Less than 120 milliseconds	•	**Typical latency** Less than 120 milliseconds
Typical Packet Loss 0.08%	•	**Typical Packet Loss** 0.08%

Network Management

Application-specific network management practices?	**Yes**
Subscriber-triggered network management practices?	**Yes**
More details on network management	
Privacy	See our privacy policy
Complaints or Inquiries	To contact us:online/(123)456-7890; To submit complaints to the FCC: online/(888)225-5322

Learn more about the terms used on this form and other relevant information at the FCC's website.

Broadband Facts

Fixed broadband consumer disclosure

Choose Your Service Data Plan for 50Mbps Service Tier

Monthly charge for month-to-month plan	**$60.00**
Monthly charge for 2 year contract plan	**$55.00**
Click here for other pricing options including promotions and options bundled with other services, like cable television and wireless services.	

Other Charges and Terms

Data included with monthly charge	**300GB**
Charges for additional data usage – each additional 50GB	**$10.00**
Optional modem or gateway lease – Customers may use their own modem or gateway; click here for our policy	**$10.00/month**
Other monthly fees	**Not Applicable**
One-time fees	
Activation fee	**$50.00**
Deposit	**$50.00**
Installation fee	**$25.00**
Early termination fee	**$240.00**

Government Taxes and Other Government-Related Fees May Apply: Varies by location

Other services on network

Performance - Individual experience may vary

Typical speed downstream	**53 Mbps**
Typical speed upstream	**6 Mbps**
Typical latency	**35 milliseconds**
Typical packet loss	**0.08%**

Network Management

Application-specific network management practices?	**Yes**
Subscriber-triggered network management practices?	**Yes**
More details on network management	
Privacy	See our privacy policy
Complaints or Inquiries	To contact us: online/(123)456-7890; To submit complaints to the FCC: online/(888)225-5322

Learn more about the terms used on this form and other relevant information at the FCC's website.

Source: FCC

program.[15] The FCC granted a similar safe harbor in its recent guidance for the 2015 rules.[16] Beyond that, ISPs are free to choose how to calculate broadband performance at their own discretion.[17] However, even as the Measuring Broadband America program continues to serve as a safe harbor for actual performance disclosure, ISPs that do not participate in the program and the MBA program itself have an opportunity to further refine broadband performance measurement to align with key best practices, as detailed in this paper.

Although there are a number of established methodologies for measuring broadband performance, not all tests assess performance in the same way. There are also diverse methods for how raw data is processed and analyzed. Depending on subtle methodological specifications not readily apparent to the average consumer, there is potential for wide disparities in performance measurement depending on who is collecting, publishing, and releasing the data.[18] As such, internet performance data drawn from disparate methodologies are like apples and pears–complementary, perhaps, but not interchangeable.

The ongoing implementation and enforcement of the Open Internet Order's transparency rules provides a critical opportunity to examine and elevate internet performance measurement, but as we note, these recommendations are broadly applicable in a variety of contexts.[19] Given the potential for disparity between two different tests of internet performance, consumers, researchers, and ISPs benefit from a clear understanding of how methodology affects measurement.

The ongoing implementation and enforcement of the Open Internet Order's transparency rules provides a critical opportunity to examine and elevate Internet performance measurement.

In this paper, we examine the factors that affect broadband performance, and highlight the benefits and tradeoffs of different testing methodologies, analytical practices, and measurement regimes. As a case study, we review the methodology and analytical choices of Measuring Broadband America, and the implications those choices have for consumers. By our analysis, MBA itself does not fully achieve best practices for data transparency. We conclude by stressing that the most useful broadband performance data will be data collected from a consistent, reproducible methodology that provides full transparency to those using the data into its underlying assumptions, and in turn, the data's strengths and limitations.

THE FACTS ON INTERNET PERFORMANCE

What are the Key Performance Metrics for Broadband Internet?

When evaluating an internet service plan, customers are most concerned about two factors: price and speed.[20] Fixed internet service providers tend to advertise by price per month and download speed (in Megabits per second) alone. Of course, download and upload speeds actually belie a more complicated set of factors that shape a user's experience. As previously noted, there are now four main performance metrics that ISPs must disclose to consumers: **upload speed**, **download speed**, **packet loss**, and **latency**.

Upload speed refers to the rate at which data is transferred from the user's device to the network, and **download speed** is the rate at which data is transferred in the reverse, to the user.[21] The FCC currently defines broadband service as having download speeds of 25 Mbps, and upload speeds at 3 Mbps.[22] In some areas of the U.S., consumers have access to internet with ultra high-speed Gigabit connections, which transfer data at speeds reaching 1000 Mbps.[23]

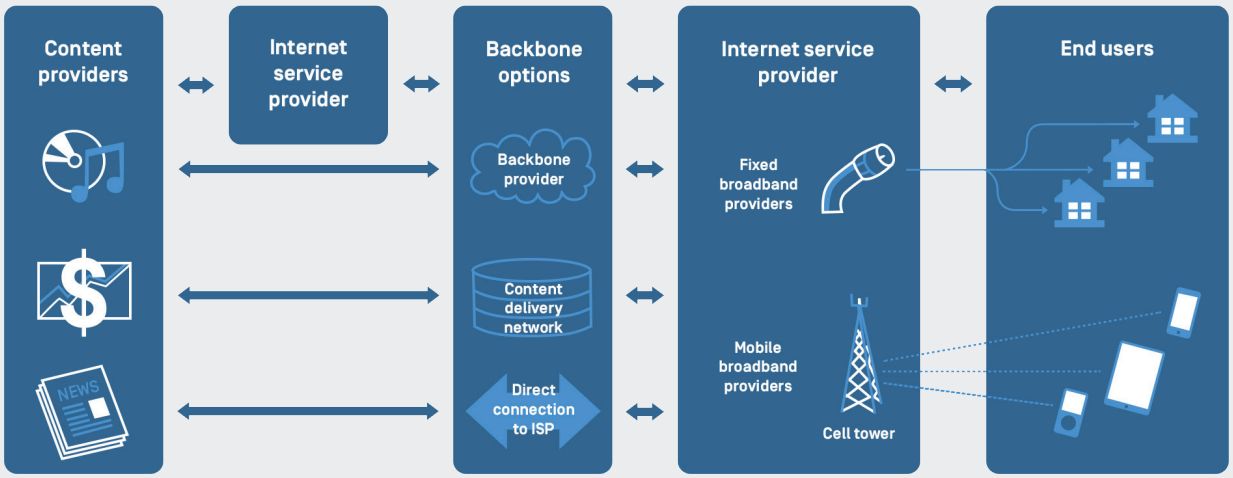
Packet loss is the percentage of data that is lost in transmission, and is most commonly caused by congestion along the route or interference on the network. A small amount of packet loss is expected, but higher packet loss can affect the perceived quality of internet applications, particularly video-heavy ones.[24]

Latency is a measure of time in milliseconds that it takes for one packet of data to travel to another host, and it increases the further that a data packet must travel in order to reach its destination.[25] Congestion on the data's route through the network can also increase latency, and high latency has particularly detrimental effects for real-time applications like gaming, internet voice calls, videoconferences, and streaming media.[26] A fifth common network performance indicator is jitter, which measures the variance in latency. Minimal jitter, which is desirable, means that packets were always delivered at the same time.[27] Jitter is not part of the FCC's required performance disclosures.

What Factors Affect Broadband Internet Performance?

In order to get to your personal device, internet content traverses a segmented route that encompasses a variety of networks often owned and managed by different entities. For example, data that originates with a content provider (like,

Figure 3 | Schema of Broadband Information Flows



Source: Adapted from the GAO

a server owned by a video streaming service), may first travel through a service provider to another provider providing an internet backbone service (transit), and then through a consumer broadband provider to arrive at your smartphone or laptop (Fig. 3). Loss of quality can occur at various points along this "internet supply chain," be it at an interconnection point (where ISP networks link up with transit or other provider networks), or within a certain network segment. Degradation of internet quality can also occur at the very last mile or within a local network. Outdated routers in the home can also limit performance, and connections can appear slow when multiple users, devices, or data-intensive applications try to consume content simultaneously.[28]

For the consumer, it is extremely difficult to pinpoint the weakest link in this data chain.[29] A subscriber may be paying for a plan advertised at 50 Mbps, but her experienced speeds are likely to vary depending on these factors. ISPs frequently market their products using "up to" language, and it is unclear how ISPs have calibrated these advertised speeds to the average performance experienced by the end user.

How Do Consumers Get Information About Broadband Performance?

Consumers can get information about internet service performance from a handful of sources. First are the providers themselves, who can offer redress options and troubleshoot support. Informed consumers might also turn to the Measuring Broadband America program or other FCC resources for more detailed information. Finally, many consumers turn to third-party speed tests offered as on-demand web or mobile applications.

External Speed Tests

Examples of consumer-facing speed tests available online include: Ookla's Speedtest.net, Google's Video Quality Report, the Netflix Speed Test, and the Network Diagnostic Test (NDT) running on the Measurement-Lab (M-Lab) platform. M-Lab is a consortium of research, industry and public-interest partners, including OTI. Ookla is a popular option that reports that it has provided over 8 billion speed tests around the world through its website Speedtest.net.[30] Notably, the five largest ISPs also provide their customers with a speed test operated by Ookla.

These external speed tests operate on a similar principle. Pieces of data are sent between a client (the consumer's device, in many cases) and some distant server, and the test records performance characteristics like speed, latency, and jitter.[31] The tests also have very similar user experiences: after navigating to the webpage, the user clicks a button and shortly receives a read out of their broadband performance.

However, these high-level similarities break down at the parameter level, where subtle differences can have dramatic impacts on performance measurement read outs. For example, one important methodological specification is the number of concurrent connections used to send the data. M-Lab's NDT test attempts to transfer as much data as possible over a single connection to a server in order to measure performance.[32] The Ookla Speed Test takes a "multi-threaded" approach, using up to 16 streams.[33] There is no right or wrong test configuration, but depending on the configuration the test provides a different performance perspective to the user.

Table 1 | Key Internet Performance Characteristics and Terms

Download speed	The rate at which data is transferred from the network to the user's device
Upload speed	The rate at which data is transferred from the user's device to the network
Latency	Time in milliseconds that it takes for one packet of data to travel to another server in the network
Packet loss	The percentage of data that is lost in transmission
Jitter	The amount of variance in network latency
internet content provider	Any individual entity that provides any content, application, or service over the internet
Content delivery network	A network of distributed servers used to deliver web content based on geographic proximity
Backbone provider	Key data routes between core, interconnected networks and routers on the internet
Interconnection point	The link between a service provider's network with equipment, facilities, or another network not belonging to that service provider
Server	A computer that hosts and provides centralized data and content to other computers on the network
Client	A piece of computer hardware or software that relies on and communicates with a server
Path	The route that a data packet takes from one point (can be a content provider, a user's mobile device, etc.) on a network to some other point

M-Lab, on the other hand, is a proponent of single-threaded testing as a methodological choice for the purpose of measuring network conditions on the consumer's broadband connection. Multi-threaded testing has a higher tolerance for background packet losses, and can obfuscate deficiencies in the connection. Thus, multi-threaded testing is distorted towards better performance read-outs compared to normal browsing behavior on congested shared links.

Another key element in speed test configuration is whether the test crosses an interconnection boundary. Congestion at interconnection points has been identified as a leading contributor to poor broadband performance, particularly for streaming video content.[34] If a test that measures performance from a consumer device only sends data to a server local to the ISP's network (a common configuration for the Ookla speed test implemented on ISP sites), it won't reveal problems like interconnection-related congestion.

Larger Performance Studies

Although they are not typically geared toward customers, broader studies of broadband performance like the FCC's Measuring Broadband America or Akamai's State of the internet reports can be good resources for information about broadband performance.[35] Typically, these reports are written for industry and policy audiences, and data is collected across a period of time and aggregated across a larger population. On the other hand, individual tests like those offered by Ookla and M-Lab provide information for a specific user at a specific moment in time, and therefore are more useful for diagnosing immediate network issues.

Similarly, because these larger longitudinal studies collect broad, multi-variable data sets, their methodologies are often more complex. The scale of these studies also exacerbates the impact of the methodological choices made in data collection practices, making transparency all the more important.

GOALS AND BEST PRACTICES FOR BROADBAND MEASUREMENT

For broadband internet, a number of factors impact performance measurement; so do the ways in which performance data is aggregated and analyzed. If the purpose of performance measurement is indeed to inform consumers and other members of the internet ecosystem, there are two key best practices for internet performance measurement:

First, performance measurement methods should strive to be representative of the end user's average experience. Measurement should be conducted from the full-path perspective of a consumer, and include performance across interconnection points and at peak hours.

Second, the performance measurement methodology must be transparent and linked to the data. For those seeking to use performance data as part of decision marking—whether they are consumers or policymakers—it is critical to understand the specific methodological choices made by a given test, and thus understand the assumptions that underpin the data.

> **Internet performance degradation at interconnection points is a prime area where consumer harm occurs.**

Performance Measurements Should Seek to Replicate the End User Experience: Interconnection Points and Peak Hours

In the words of an FCC filing by the National Cable Television Association (NCTA), internet performance measurement "should replicate the real-life consumer experience of streaming a video."[36] A testing methodology should not simply strive to capture the performance and capacity of an individual ISP's network on its best day, or the fastest possible round-trip time between a computer and a measurement server. A measurement methodology employed by an ISP or the FCC should be configured to capture service disruptions that occur because of congestion or on the network at interconnection points.

As we noted earlier, internet performance degradation at interconnection points is a prime area where consumer harm occurs. It is therefore important that methodologies dedicated to measuring and representing the consumer experience be conducted across interconnection points. Furthermore, measurement of interconnection points that do not focus on full-path performance—that is, from a consumer device to a server located across network boundaries—will also not accurately capture the impact of interconnection performance degradation on consumers.

For example, if a test focuses just on interconnection points and the border routers of two adjoining network operators, it might miss the overall performance degradations caused by congestion. To understand how, it is helpful to consider the analogy of a three-lane freeway, where traffic is closed in two of the three lanes. The closures force cars to queue up to merge into a single lane. While the two lane closures may only be along a small segment of the freeway, cars can congest and slowdown many miles before they reach the one-lane section. In fact, it is likely that once cars reach that one-lane section, they will speed up. The same speed pattern occurs at congested interconnection points: traffic slows down on either side, but may move smoothly through the connection point responsible for the slowing.[37] Thus, interconnection measurement must measure the full path, and not simply the performance between interconnecting border routers, if it is to claim to be representative of the consumer experience.

To continue the traffic metaphor, internet performance should also be measured under conditions reflective of the internet "rush hour," when networks are at peak demand. The FCC currently defines peak hours as 7:00 pm-11:00 pm on weeknights.[38] Current data indicates that this continues to be appropriate, but internet use behaviors may shift with the introduction of new services, such as the increasing availability of internet-enabled objects ("Internet of Things") that transmit data throughout the day. In the future, the FCC may consider reexamining the definition of "peak hours," particularly when informed by real-time data from ISPs or other sources about granular patterns in congestion and usage over time. It is also worth noting that patterns of device use on wireless/mobile broadband networks may differ substantially from wireline ones.

Performance Measurements Should Have a Stable and Transparent Methodology

We recognize that there are a number of valid and complementary approaches to measuring broadband performance, and that different test methodologies expose different aspects of performance. The merits and disadvantages of the individual methodologies might vary by tool and use case: what do you want to know, and is your measurement designed to expose it? For the purposes of consumer disclosure, an ISP may not have the wherewithal or technical capacity to accurately simulate average experiences for each constituent group they serve.

However, no matter which way an ISP chooses to measure speed, latency, or packet loss, to ensure transparency and utility, ISPs must make their measurement and analytic methodologies open, replicable, and comparable.

Whatever methodology is used, it should be sufficiently and clearly documented in order to provide those relying on the data with full transparency into its underlying assumptions, and as such, an ability to calibrate their decision making based on a clear understanding of the data's strengths and limitations. As we have seen, many factors impact measurement, as do the ways that the data is aggregated and reported. Methodology must in turn be transparent at each of those stages.

Ideally, broadband performance data should be accompanied with detailed methodological specifications to provide a way for external parties to validate and replicate how ISPs are collecting and compiling their performance information. The model specification would enable a third party to replicate the measurement methodology along the same network perspectives. Such reproducibility would require access to the measurement program's source code, details about server instrumentation and hardware, a clear indication of the infrastructure paths, and an explanation of the analytic choices made when processing and aggregating the data.

Safe Harbors

Currently, there are two safe harbors for ISPs related to the Open Internet Transparency Rules, one for measurement practices and one for consumer

> **Whatever methodology is used, it should be sufficiently and clearly documented in order to provide those relying on the data full transparency into its underlying assumptions, and as such, an ability to calibrate their decision making based on a clear understanding of the data's strengths and limitations.**

disclosure. First, ISPs are offered a voluntary safe harbor for performance measurement rules through participation in the Measuring Broadband America program. Nearly all of the largest ISPs chose to do so, and thus, since the launch the program, the primary method by which ISPs "disclose" broadband performance measurements to the public has been an indirect way–through the Measuring Broadband America reports. This safe harbor was first erected in 2011, and reaffirmed in the 2015 Open Internet Order.[39] The second safe harbor stipulates that an ISP would also be in compliance with the transparency rules for consumer disclosure as long as they adopt the FCC's standardized disclosure formats, as previously discussed in this paper. By participating in either safe harbor, ISPs are held to be in compliance with the respective provisions inside the FCC's transparency rules. The first safe harbor will be detailed further in the next section, where we will discuss the Measuring Broadband America, both as a case study of broadband performance measurement methodology and public policy regarding transparency.

CASE STUDY: MEASURING BROADBAND AMERICA

Measuring Broadband America is an ambitious program to collect and analyze bulk broadband performance data from across the United States. Launched by the FCC in 2011, the program originated as a recommendation in the 2010 National Broadband Plan. Measuring Broadband America publishes an annual report, now in its fifth iteration, on performance findings for both fixed and mobile internet.[40] For the purposes of this paper, we will primarily focus on the fixed broadband component.[41]

In order to survey the state of broadband performance in the United States, the MBA program collects wireline performance measurements using a sample population of about 6,000 volunteer consumer broadband subscribers. The MBA sample size includes geographically and demographically diverse subscribers from 14 of the largest ISPs, and the FCC claims that the volunteer panel is representative of 80 percent of the residential marketplace.[42] Each volunteer receives a "Whitebox" hardware device, which conducts the measurements, that is installed in the volunteer's home and directly connected to the consumer's internet connection.[43] The devices themselves are similar in size and shape to a traditional broadband router, and the devices run performance tests periodically throughout the day.

Although hardware-based measurement is more intensive and expensive than software-based alternatives (e.g. web application speed tests), it offers several key advantages for the purposes of the MBA study. An automated hardware test removes certain human sampling biases, allows for a 24-hour measurement profile, provides for greater technical standardization across the sample size, and is less likely to be affected by exogenous factors like the number of machines on a home network or a misconfigured network.[44]

The MBA program is administered through a partnership between the FCC and SamKnows, an internet measurement and analytics firm that has also partnered with the European Commission and the governments of the United Kingdom, Brazil, and Singapore to conduct similar performance studies.[45] SamKnows is also a M-Lab partner. The FCC describes the program to be "built on principles of openness and transparency," and each annual Measuring Broadband report is accompanied by a technical appendix that describes the overarching methodology, from the recruitment of volunteers to the architecture of the measurement platform. The FCC makes its measurement data available for bulk download, and has documented MBA's analytical methodology in a case study and white paper.[46] SamKnows has opened up the source code

for the Whitebox's operating system, and some of the methodologies for the Whitebox measurements have been described in a white paper.[47]

Unfortunately, it appears that MBA does not fully meet the best practices for performance measurement that we identify earlier in this paper. While the myriad MBA reports and Technical Appendices are valuable for interpreting and understanding the study findings, MBA lacks comprehensive transparency that would allow a third party to replicate and independently verify MBA test results. For example, the code for the measurement platform—the application running on the Whitebox device—is not open and available for inspection.[48] As noted by the GAO, the MBA program also may not accurately reflect the experience of consumers dealing with interconnection problems. The MBA measurement application is designed to test the performance of the ISP's network alone, and the FCC has previously explicitly excluded data from its final reports after discovering that it had been affected by congestion at interconnection points.[49]

In addition, the MBA program has also created an interesting policy conundrum. Although it was intended to enhance information available to consumers, it is not particularly lay-consumer friendly. The MBA reports are dense and written for an audience of expert researchers and regulators; the data is released in very technical formats, not easily understood by the lay consumer.

For example, many of the largest ISPs currently satisfy FCC transparency requirements related for performance measurement through participation in the program, and yet many consumers are unaware that the MBA report exists or that performance measures are mandated of ISPs.[50] Moreover, the MBA does not account for measurement of interconnection-related harms, harms that both M-Lab and OTI have documented and examined extensively.[51]

Several stakeholders voiced support for measurement guidance, in the contect of the 2015 transparency rules, to account for harms related to interconnection disputes. Level 3, a company that operates as an internet backbone provider, proposed an internet measurement scheme that puts interconnections at the forefront, stating that ISPs should not "be able to hide poor, inconsistent performance behind methodologies that provide a misleading 'average' performance statistic."[52] Netflix, an internet content provider that has previously complained to the FCC about interconnection issues with ISPs, stated that "meaningful disclosure and assessment of network performance and the user experience should include information on performance to servers and other endpoints located across interconnection points."[53]

Cogent Communications Group, another internet backbone service provider, called for the following requirements: that ISPs disclose performance metrics for their own, proprietary services to create a benchmark against which the download speeds of unaffiliated content can be compared; that ISPs disclose sufficient data about interconnection points and network congestion/capacity at those interconnection points (to backbone providers, other delivery networks, peers); and that ISPs promptly inform consumers of any practices that block or degrade the performance of content or an application from any particular internet content provider, including decisions not to augment capacity at congested points.[54]

The FCC did not set formal and explicit baseline best practices for broadband measurement (e.g. which segments of the network must be tested, and over which periods of time) in its May 2016 guidance, focusing instead on the availability of the MBA as a safe harbor for disclosure metrics. Further, the language in the notice seems to suggest that measurement close to interconnection points with content providers would be sufficient,[55] though it also acknowledges that other measurement arrangements would be appropriate.[56]

If the ultimate goal of the FCC transparency rules is to provide consumers with meaningful and

actionable information about their broadband internet service, then there is still room for improvement. Whether an ISP is participating in one or both safe harbors, there are still too many opportunities for confusion or inadequate disclosures, particularly from the perspective of the average consumer. Broadband performance methodologies are frequently unreported and do not seem to be standardized across companies. This opactiy hinders the ability of customers to effectively comparison shop, and hinders the ability for civil society actors or the FCC to validate and judge the ISP's behavior. At minimum, clear disclosures about the underlying methodologies used would be extremely helpful to the public, as well as researchers, in understanding the distinctions in the measurement results.

Finally, now that MBA has been confirmed as a safe harbor for the transparency rules, the program should be refined to conform with the best practices detailed in this paper (particularly those that would capture interconnection harms). Doing so will provide an important measurement baseline for those ISPs that participate in the MBA, but also model these practices for ISPs that decline participation in the program.

Table 2 | Key Recommendations for Measuring Broadband Performance

Methodology Best Practices
1. Data should be collected using a consistent and reproducible methodology.
2. Measurement methodology should accurately reflect the experience of the end user, and uphold standards of transparency and openness by providing precise specifications for measurement and analysis.
a. Measurement should capture performance over interconnection points and at peak hours,
b. Methodology should allow for third-party oversight and verification,
c. All methodological and analytic choices should be available in full transparency,
d. Open software measurement clients and back end (the measurement application) should be open source, and
e. Methodology in analysis and processing of the data should be open.
3. Standardized disclosure formats should include baseline best practices for broadband measurement so that customers can confidently gauge their own connectivity against what is expected and what others receive.

CONCLUSION

In any market, informed consumers are a necessary ingredient of the virtuous cycle of innovation that leads to reduced costs, new products, and new entrants in the marketplace. Unfortunately, this cycle is hobbled in the American broadband market, where many consumers remain uninformed and frustrated about broadband internet services.

Over the past five years, the FCC has publicly committed to increasing transparency in the broadband market to help consumers identify the services that best fit their needs and budgets.[57] internet service providers are now required to make public-facing disclosures that, for each service plan, detail fees, metrics of network performance, network management practices, and other general service descriptions. Further, ISPs are incentivized to adopt standardized consumer disclosure labels designed to show this information in an at-a-glance format.

The FCC should further its commitment to transparency by addressing how ISPs choose to measure broadband internet performance. Measuring internet performance is a complicated, but critical subject to internet transparency policy. The resources currently available to consumers are not providing adequate information about the services for which they pay and on which they rely.

Different methodologies are suitable for different purposes, and although there is not necessarily a single "best methodology" for measuring internet performance, a measurement methodology should be chosen with care, uphold best practices, and provide transparency to users. It should not take an expert to discern what methodological assumptions undergird performance data provided about internet services.

> **Regulators and service providers should continue to work to improve transparency not only about internet speeds, but how those speeds are measured and by whom.**

Regulators and service providers should continue to work to improve transparency not only about internet speeds, but how those speeds are measured, and by whom—with the best interests of the consumer in mind.

APPENDIX. MOBILE BROADBAND

Although this paper does not focus on mobile broadband performance, mobile broadband is an increasingly important way through which Americans access the internet. According to the Pew Research Center, by 2019, traffic from wireless and mobile devices will exceed traffic from wired devices, and smartphone ownership among American adults has nearly doubled since 2011, to 64%.[58] This appendix will provide a brief discussion of the factors impacting mobile broadband internet performance.

As in the fixed broadband context, methodologies for mobile broadband performance should also be representative of the end user, and uphold a commitment to transparency. However, mobile broadband internet differs from wireline service in technical and practical ways that strongly impact what would constitute a transparent measurement regime.

First and foremost, mobile internet content is delivered to consumer devices wirelessly through cell towers, which transmit data over one or multiple spectrum channels (depending on the generation of the technology). In comparison with fixed line internet service, this technological difference greatly increases the number of variables that affect performance.[59] Wireless connections are susceptible to interference from other objects that emit radio waves (which includes household devices like Microwave ovens), and connection quality can also vary with distance from the tower, signal strength, and with the presence of physical barriers like walls, buildings, or people.[60] The number of individuals in a given area who are simultaneously attempting to use a mobile network can also greatly impact performance, creating long or short moments of congestion that don't necessarily align with traditionally defined "peak hours" of use.

Other factors that can affect mobile internet include device type, operating system and firmware, number of applications running on the device, and whether or not the device is in motion. Standard network management practices for mobile internet service providers also differ from the wireline context: during times of peak demand, a provider might prioritize certain types of data or certain service plans.[61] The existence of data caps is another factor that could affect mobile internet performance and its measurement. All of these factors can compromise mobile internet performance– sometimes within the domain of the provider or the customer, and many times outside of either's control.

In turn, the additional variables for mobile internet complicate methodology design for performance measurement. Wireless performance can vary drastically by time and location, and in seemingly

unpredictable ways. The FCC has been grappling with the challenge of measuring mobile broadband performance since 2010.[62] Aside from a brief hiatus in the application's development in 2012, the FCC is currently crowdsourcing mobile performance measurement data for inclusion in the Measuring Broadband America reports from consumers through a mobile app, available for both iOS and Android operating systems.[63] By contrast, Ofcom, the main telecommunications regulator for the UK, commissioned a discrete performance study utilized rotating handsets and SIM cards, and did not solicit data from consumer volunteers.[64]

> **However, mobile broadband internet differs from wireline service in technical and practical ways that strongly impact what would constitute a transparent measurement regime.**

Like the wireline performance test, the FCC mobile application was developed in partnership with SamKnows, and can run a performance test on a randomly scheduled basis, or upon request of the user. Like its fixed-line analog, the performance test captures on speed, latency, packet loss, as well as mobile-relevant structural data such as Received Signal Strength Indicator (RSSI), Bearer, Carrier, and CellTowerID. The mobile measurement methodology is publically available as well, and the source code for the app is open source and available to the public via Github, exceeding the fixed line platform.[65]

Privacy concerns are a significant distinction between mobile and wireline broadband performance measurement. According to the FCC, the agency's privacy considerations during the app's development included "analysis of data's statistical properties by privacy experts to ensure anonymity and prevent re-identification prior to release of data," and the multi-month development of the Mobile App Terms and Conditions and Privacy Policy in a "privacy by design" process. Because of privacy concerns, bulk data is not released publicly through the Mobile Measuring Broadband America report.[66]

Compared to the FCC's wireline tests, MBA mobile requires little, if any effort on the part of a mobile service provider. The decision to develop a standalone mobile application as a means of conducting broadband performance measurement, rather than rely on a hardware device, has allowed the FCC to effectively crowdsource data from consumers. In the mobile context, the FCC, and other interested groups might benefit from an alternative approach to mobile broadband tmeasurement, which take in the design challenges of defining appropriate geographic areas for reporting and the possibility for disclosing speed ranges rather than integer numbers.

Notes

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[22] Micah Singleton, "The FCC has changed the definition of broadband," The Verge (Jan. 20, 2015), available at http://www.theverge.com/2015/1/29/7932653/fcc-changed-definition-broadband-25mbps; Note that the FCC nonetheless still uses the 10mbps down/1mbps up within the context of the Universal Service Fund, see Federal Communications Commission, "FCC increases rural broadband speeds under Connect America Fund," News Release (Dec. 11, 2014) available at https://apps.fcc.gov/edocs_public/attachmatch/DOC-330989A1.pdf.

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[26] GAO Report, at 4.

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[39] FCC Enforcement Bureau and Office of General Counsel Issue Advisory Guidance for Compliance with Open Internet Transparency Rule, GN Docket No. 91-191, WC Docket No. 07-52 (rel. Jun. 30, 2011), available at https://apps.fcc.gov/edocs_public/attachmatch/DA-11-1148A1.pdf. ("2011 Advisory Guidance"); see also "Enhanced Transparency Requirements Expand Current Disclosure Obligations (But Temporarily Exempts Smaller Providers)," supra note 15.

[40] Federal Communications Commission, Measuring Broadband America, available at https://www.fcc.gov/general/measuring-broadband-america.

[41] The appendix to this paper discusses some mobile concerns.

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[43] Id.

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